COOPER

GENERAL SPECIFICATIONS
FOR STEEL HIGHWAY AND
ELECTRIC RAILWAY
BRIDGES

"The most perfect system of rules to insure success must be interpreted upon the broad grounds of professional intelligence and common sense."
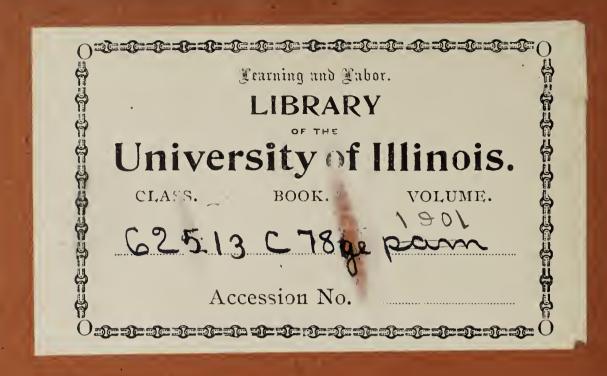
GENERAL SPECIFICATIONS

FOR

STEEL HIGHWAY AND ELECTRIC RAILWAY BRIDGES AND VIADUCTS.

NEW AND REVISED EDITION, 1901.

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Consulting Engineer.

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General Specifications for Steel Highway and Electric Railway Bridges and Viaducts.

FIFTH EDITION.

1901.

GENERAL DESCRIPTION.

Bridges under these specifications are divided into six Classes. classes, for different localities and various loadings, as follows: (§ 38.)

Class A1. City bridges having buckle-plate floors and an accepted form of paving resting on a concrete base. (§ 29.)

Class A2. City bridges having plank flooring. (§ 29.)

Class B. Suburban bridges or Interurban bridges carrying heavy electric cars. (§ 29.)

Class C. Town or country bridges carrying light electric cars or bridges carrying heavy loads from quarries or manufactories.

Class D. Country bridges carrying only ordinary highway traffic.

Class E1. Bridges carrying heaviest motor cars, only.

Class E2. Bridges carrying light motor cars, only.

1. All parts of the structures shall be of wrought steel, except the flooring, floor joists and wheel guards, when wooden floors are used. Cast-iron or cast-steel may be used in the machinery of movable bridges, for wheel guards, and in special cases for bed-plates.

Kind of Girders. 2. The following kinds of girders shall preferably be employed :

Spans, up to 25 feet ____ Rolled beams.
    "   20 to 40 " ____ Rolled beams or plate girders.
    "   40 to 80 " ____ Riveted plate or lattice girders.
    "   80 to 120 " ____ Lattice girders.
    " over 120 " ____ Lattice or pin-connected trusses.

Length of Span. In calculating strains the length of span shall be understood to be the distance between centres of end pins for trusses, c. to c. of trusses for cross floor beams, and between centres of bearing plates for all longitudinal beams and girders.

Form of Trusses. 3. Unless otherwise specified, the form of bridge trusses may be selected by the bidder; for through bridges, the end vertical suspenders and two panels of the lower chord, at each end, will be made rigid members. In through bridges, the floor beams shall be riveted to the posts, above or below the pins.

Lateral Bracing. 4. All lateral, sway and portal bracing must be made of shapes capable of resisting compression as well as tension, and must have riveted connections. All bridges must have lateral struts at the ends, except where end floor beams act as such.

Trestle Towers. 5. Each trestle bent shall, as a general rule, be composed of two supporting columns, and the bents united in pairs to form towers; each tower thus formed of four columns shall be thoroughly braced in both directions, and have struts between the feet of the columns. The feet of the columns

must be secured to an anchorage capable of resisting double the specified wind forces. (§ 40.)

6. Each tower shall have sufficient base, longitudinally, to be stable when standing alone, without other support than its anchorage. (§§ 40, 43.)

7. Tower spans for high trestles shall not be less than 30 feet.

8. Where footwalks are required, they will generally be Foot-walks. placed outside of the trusses and supported on longitudinal beams resting on overhanging steel brackets.

9. A strong and suitable handrailing will be placed at Railing. each side of the bridge and be rigidly attached to the superstructure.

10. For all through bridges there shall be a clear head-Head-room. room of 15 feet above the floor, for Classes A, B, C and E; and a minimum head-room of 12½ feet for Class D.

11. In comparing different proposals, the relative cost of Proposals. the required masonry or changes in existing work will be taken into consideration.

12. Contractors in submitting proposals shall furnish complete strain sheets, general plans of the proposed structures, and such detail drawings as will clearly show the dimensions of all the parts, modes of construction and the sectional areas.

13. Upon the acceptance of the proposal and the execution of contract, all working drawings required by the Engineer must be furnished free of cost.

14. No work shall be commenced or materials ordered Approval of Plans. until the working drawings are approved by the Engineer in writing; if such working drawings are detained more than one week for examination, the Contractor will be allowed an equivalent extension of time.

FLOOR SYSTEM.

15. All cross floor beams will be rolled or riveted steel Floor Girders. girders, rigidly connected to the trusses at the panel points.

16. All longitudinal girders of bridges of Classes A1 and

A2 will be of steel; all *track* stringers of bridges of Classes B, C and E will be of steel. Unless otherwise specified all other longitudinal girders of Classes B and C will be of steel. The longitudinal girders of bridges of Class D may be either of wood or steel. When the longitudinal beams are of steel, they must be securely fastened to the cross floor beams.

COUNTRY BRIDGES.

Wooden Floor.   17. Wooden floor joists will be spaced not over 2 feet centres, and will lap by each other, so as to have a full bearing on the floor beams, and will be separated $\frac{1}{2}$ inch for free circulation of air. Their scantling will vary in accordance with the length of panels selected, but shall never be less than 3 inches, or one-fourth of depth in width. When spaced not over 2-foot centres, one joist shall be considered as carrying only two-thirds of the concentrated live load.

18. The floor plank shall be _____ inches thick, laid with $\frac{1}{4}$-inch openings, and spiked to each supporting joist. When this is to be covered with an additional wearing floor (§ 19), it must be laid diagonally and with $\frac{1}{2}$ inch openings; all plank shall be laid with the heart side down. The floor plank must have a thickness, *in inches*, at least equal to the distance apart of these beams, *in feet*, with a minimum thickness of $2\frac{1}{2}$ inches. The floor plank must bear firmly upon the beams and be securely fastened to the same.

19. Where specified an additional wearing floor $1\frac{1}{2}$ inches thick of white oak plank shall be placed over the above. (§ 18.)

20. The footwalk plank will be 2 inches thick and not over 6 inches wide, spaced with $\frac{1}{2}$ inch openings.

21. There will be a wheel guard, of a scantling not less than 6 x 4, on each side of the roadway to prevent the hubs of wheels striking any part of the bridge. It should be blocked up from the floor to admit drainage and ventilation.

Allowed strain on Timber.   22. The maximum strain allowed upon the extreme fibre of the joist will be 1,200 pounds per square inch on yellow

pine and white oak, and 1,000 pounds per square inch on white pine and spruce.

CITY BRIDGES.

23. Buckle-plates will be not less than $\frac{5}{16}$ inch thick and Buckle Plates. will crown 2 inches at the centre. Plates of this thickness and crown may be used to widths of 4 feet under the roadway and 5 feet under the footwalks. (§§ 93–96.)

24. Bridges with buckle plate floors will have a suitable Curbs and Guards. metal curb on each side of the roadway to hold paving and act as a wheel guard. The wheel guard must be so arranged that it can be removed and replaced when worn or injured. There will also be a metal edging strip on each side of the footwalks to hold the paving in place.

25. The concrete over buckle-plates shall be at least 3 Concrete. inches thick on the roadway and 2 inches thick on the sidewalks, over the highest point to be covered, not counting rivet heads.

26. The sidewalks shall slope 1 inch in 5 feet, preferably towards the roadway. The roadway shall crown from curb to centre 1 inch for each 10 feet of the roadway width. The depth of the curb will be 6 inches.

27. The subgrade, top of concrete, for the sidewalks will be _____inches below final grade and slope.

The concrete over roadway will be laid to the correct crowning and elevation to allow _____inches for the selected paving.

28. Scuppers must be provided at frequent intervals along Scuppers. the curbs or wheel guards for drainage and for passing the sweepings and snow, clear from contact with any parts of the tracks or floor system.

29. Classes A and B shall be designed to carry at any Double Track. future time a double-track electric railway.

ELECTRIC RAILWAY BRIDGES.

30. The wooden floors will consist of transverse ties or Wooden Floor. floor timbers; their scantling will vary in accordance with

the design of the supporting steel floor. (§ 22.) They shall be spaced with openings not exceeding six inches, and shall be notched down ½ inch and be secured to the supporting girders by ¾-inch bolts at distances not over six feet apart. For deck bridges the ties will extend the full width of the bridge, and for through bridges at least every other tie shall extend the full width of bridge for a footwalk.

Guard Timbers.   31. There shall be a guard timber (scantling not less than 5 x 7″) on each side of each track, with its inner face parallel to and at_____feet_____inches from centre of track. Guard timbers must be notched one inch over every floor timber, and be spliced over a floor timber with a half-and-half joint of six inches lap. Each guard timber shall be fastened to every third floor timber and at each splice with a three-quarter (¾) inch bolt. All heads or nuts on upper faces of ties or guards must be countersunk below the surface of the wood. (§ 76.)

32. The guard and floor timbers must be continuous over all piers and abutments.

33. The floor timbers from centre to each end of span must be notched down over the longitudinal girders so as to reduce the camber in the track, as directed by the Engineer.

34. All the floor timbers shall have a full and even bearing upon the stringers; no open joints or shims will be allowed.

35. On curves the outer rail must be elevated, as may be directed by the Engineer.

Clear width.   36. In all through bridges the clear width from the centre of the track to any part of the trusses shall not be less than seven (7) feet at a height exceeding one foot above the rails where the tracks are straight, and an equivalent clearance, where the tracks are curved.

37. The standard distance, centre to centre of tracks on straight lines, will_____feet.

LOADS.

38. All the structures shall be proportioned to carry the following loads:

1st. The weight of metal in the structure and floor.

2d. The weight of the paving and concrete or the wooden floor, considering each foot of board measure to weigh $4\frac{1}{2}$ pounds for oak and other hard woods, and $3\frac{1}{2}$ pounds for spruce and white pine.

These two items, taken together, shall constitute "the dead load." Dead Load.

3d. A "live" or moving load, according to one of the Live Loads. following classes:

Class A1 and Class A2.—City Bridges :

For the floor and its supports, on any part of the road-way or on each of the street car tracks, a concentrated load of 24 tons on two axles 10 feet centres (assumed to occupy 12 feet in width for a single line and 22 feet for a double line), and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot.

For the trusses, loads as per Table A.

Class B.—Suburban or Interurban Bridges:

For the floor and its supports, on any part of the road-way, a concentrated load of 12 tons on two axles 10 feet centres or on each of the street car tracks a concentrated load of 24 tons on two axles 10 feet centres ; and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot of floor.

For the trusses, loads as per Table A.

Class C.—(Class B2 of former editions) :

For the floor and its supports, on any part of the road-way, a concentrated load of 12 tons on two axles 10 feet centres, or on street car track a concentrated load of 18 tons on two axles 10 feet centres ; and upon the remaining portion of the floor, including footwalks, a load of 100 pounds per square foot of floor.

For the trusses, loads as per Table A.

Class D.—(Class C of former editions.) Country High-way Bridges :

For the floor and its supports, a load of 80 pounds per square foot of total floor surface, or 6 tons on two axles 10 feet centres.

For the trusses, loads as per Table A.

Class E1.—Electric Railway Bridges, with Heavy Equipment:

For the floor and its supports, a load of 24 tons on two axles 10 feet centres, on each track.

For the trusses, loads as per Table A.

Class E2.—Electric Railway Bridges, with Light Equipment:

For the floor and its supports, a load of 18 tons on two axles 10 feet centres, on each track.

For the trusses, loads as per Table A.

TABLE A.—LIVE LOADS FOR THE TRUSSES.

	CLASS A.			CLASS B.	
Span in feet.	Pounds per lineal foot of each car track.	Pounds per square foot of remaining floor surface.	Span in feet.	Pounds per lineal foot of each car track.	Pounds per square foot of remaining floor surface.
Up to 100............	1 800	100	Up to 100..........	1 800	80
105............	1 770	99	105..........	1 770	79
110............	1 740	98	110·..........	1 740	78
115............	1 710	97	115..........	1 710	77
120............	1 680	96	120..........	1 680	76
125............	1 650	95	125..........	1 650	75
130............	1 620	94	130..........	1 620	74
135............	1 590	93	135..........	1 590	73
140............	1 560	92	140..........	1 560	72
145............	1 530	91	145..........	1 530	71
150............	1 500	90	150..........	1 500	70
155............	1 470	89	155..........	1 470	69
160............	1 440	88	160..........	1 440	68
165............	1 410	87	165..........	1 410	67
170............	1 380	86	170..........	1 380	66
175............	1 350	85	175..........	1 350	65
180............	1 320	84	180..........	1 320	64
185............	1 290	83	185..........	1 290	63
190............	1 260	82	190..........	1 260	62
195............	1 230	81	195..........	1 230	61
200 and over...	1 200	80	200 and over.	1 200	60

CLASS C.

Up to 100............	1 200	80	155..........	1 090	69
105............	1 190	79	160..........	1 080	68
110............	1 180	78	165..........	1 070	67
115............	1 170	77	170..........	1 060	66
120............	1 160	76	175..........	1 050	65
125............	1 150	75	180..........	1 040	64
130............	1 140	74	185..........	1 030	63
135............	1 130	73	190..........	1 020	62
140............	1 120	72	195..........	1 010	61
145............	1 110	71	200 and over.	1 000	60
150............	1 100	70	....	....	....

TABLE A (*Continued*)—LIVE LOADS FOR THE TRUSSES.

CLASS D.		CLASS E 1.		CLASS E 2.	
Span in feet.	Pounds per square foot of floor surface.	Span in feet.	Pounds per lineal foot of each car track.	Span in feet.	Pounds per lineal foot of each car track.
Up to		Up to		Up to	
75	80	100	1 800	100	1 200
80	79	105	1 770	105	1 190
85	78	110	1 740	110	1 180
90	77	115	1 710	115	1 170
95	76	120	1 680	120	1 160
100	75	125	1 650	125	1 150
105	74	130	1 620	130	1 140
110	73	135	1 590	135	1 130
115	72	140	1 560	140	1 120
120	71	145	1 530	145	1 110
125	70	150	1 500	150	1 100
130	69	155	1 470	155	1 090
135	68	160	1 440	160	1 080
140.	67	165	1 410	165	1 070
145	66	170	1 380	170	1 060
150	65	175	1 350	175	1 050
155	64	180	1 320	180	1 040
160	63	185	1 290	185	1 030
165	62	190	1 260	190	1 020
170	61	195	1 230	195	1 010
175	60	200 and over.	1 200	200 and over.	1 000
180	59				
185	58				
190	57				
195	56				
200 and over.	55				

The maximum strains due to all positions of either of the above "live loads," of the required class, and of the "dead loads," shall be taken to proportion all the parts of the structure.

39. To provide for wind strains and vibrations, the top Wind Bracing lateral bracing in deck bridges, and the bottom lateral brac- ing in through bridges, shall be proportioned to resist a lateral force of 300 pounds for each foot of the span; 150 pounds of this to be treated as a moving load.

The bottom lateral bracing in deck bridges, and the top lateral bracing in through bridges, shall be proportioned to resist a lateral force of 150 pounds for each lineal foot. For spans exceeding 300 feet, add in each of the above cases 10 pounds additional for each additional 30 feet.

40. In trestle towers the bracing and columns shall be proportioned to resist the following lateral forces, in addition to the strains from dead and live loads:

The trusses loaded or unloaded, the lateral pressures specified above ; and a lateral pressure of 100 pounds for each vertical lineal foot of the trestle bents.

Temperature. 41. Variation in temperature, to the extent of 150 degrees, shall be provided for.

Centrifugal Force. 42. For electric railways on curves, the additional effects due to the centrifugal force of cars single or coupled shall be considered as a live load. It will be assumed to act 5 feet above base of rail, and will be computed for a speed of 40 miles per hour.

Longitudinal Forces. 43. The strains produced in the bracing of the trestle towers, in any members of the trusses, or in the attachments of the girders or trusses to their bearings, by suddenly stopping the maximum electric car trains on any part of the work must be provided for ; the coefficient of friction of the wheels on the rails being assumed as 0.20.

44. All parts shall be so designed that the strains coming upon them can be accurately calculated.

PROPORTION OF PARTS.

Tensile Strain. 45. All parts of the structures shall be proportioned in tension by the following allowed unit strains:

Medium Steel.

For Medium Steel.

	Pounds per square inch.
Floor beam hangers, and other similar members liable to sudden loading, net section	8,000
Longitudinal, lateral and sway bracing, for wind and live load strains (§§ 6, 39, 40)	18,000
Solid rolled beams, used as cross floor beams and stringers	13,000
Bottom flanges of riveted girders, net section	13,000

	For live loads.	For dead loads.
Bottom chords, main diagonals, counters and long verticals	12,500	25,000

For swing bridges and other movable structures, the dead load unit strains, during motion, must not exceed three-fourths of the above allowed unit strains for dead load on stationary structures.

Soft Steel. *Soft Steel* may be used in tension with unit strains ten per cent. less than those allowed for *Medium Steel*.

46. Angles subject to direct tension must be connected by both legs, or the section of one leg only will be considered as effective.

47. In members subject to tensile strains full allowance Net Section. shall be made for reduction of section by rivet-holes, screw-threads, etc. (§§ 75, 79.)

48. Compression members shall be proportioned by the Compressive Strains. following allowed unit strains:

For Medium Steel.

Medium Steel.

Chord segments $P=12,000-55\dfrac{l}{r}$ for live load strains.

$$P=24,000-110\dfrac{l}{r}\text{ for dead load strains.}$$

- -

All posts of through bridges. $P=10,000-45\dfrac{l}{r}$ for live load strains.

$$P=20,000-90\dfrac{l}{r}\text{ for dead load strains.}$$

- -

All posts of deck bridges and trestles. $P=11,000-40\dfrac{l}{r}$ for live load strains.

$$P=22,000-80\dfrac{l}{r}\text{ for dead load strains.}$$

- -

End posts are not to be considered chord segments.

- -

Lateral struts and rigid bracing. $P=13,000-60\dfrac{l}{r}$ for wind strains;

for live load strains use two-thirds of the above. (§§ 42, 43, 124.)

- -

$P=$ the allowed strain in compression per square inch of cross-section, in pounds.

$l=$ the length of compression member, in inches, c. to c., of connections.

$r=$ the least radius of gyration of the section, in inches.

No compression member, however, shall have a length

exceeding 100 times its least radius of gyration for main members, or 120 times for laterals.

For swing bridges and other movable structures, the dead load unit strains during motion must not exceed $\frac{3}{4}$ of the above allowed unit strains for dead load on stationary structures.

49. For long span bridges, when the ratio of the length and width of span is such that it makes the top chords acting as a whole, a longer column than the segments of the chord, the chord will be proportioned for this greater length.

Soft Steel. *Soft Steel* may be used in compression with unit strains fifteen per cent. less than those allowed for *Medium Steel*.

50. The areas obtained by dividing the live load strains by the live load unit strains will be added algebraically to the areas obtained by dividing the dead load strains by the dead load unit strains to determine the required sectional area of any member. (§ 62.)

Alternate Strains. 51. All members and their connections subject to alternate strains of tension and compression shall be proportioned to resist each kind of strain. Both of the strains shall, however, be considered as increased by an amount equal to $\frac{8}{10}$ of the least of the two strains, for determining the sectional areas by the above-allowed unit strains. (§§ 45, 48.)

Effect of Wind on Chord Strains. 52. The strains in the truss members or trestle posts from the assumed wind forces need not be considered except as follows:

1st. When the wind strains on any member exceed 25 per cent. of the maximum strains due to the dead and live loads upon the same member. The section shall then be increased until the total strain per square inch will not exceed by more than 25 per cent. the maximum fixed for dead and live loads only.

2d. When the wind strain alone or in combination with a possible temperature strain, can neutralize or reverse the strains in any member.

Rivets, Bolts and Pins. 53. The rivets in all members, other than those of the floor and lateral systems, must be so spaced that the shearing strain per square inch shall not exceed 10,000 pounds;

nor the pressure on the bearing surface (diameter × thickness of the piece) of the rivet-hole exceed 18,000 pounds per square inch.

The rivets in all members of the floor system, including all hanger connections, must be so spaced that the shearing strains and bearing pressures shall not exceed 80 per cent. of the above limits.

The rivets in the lateral and sway bracing will be allowed 40 per cent. increase upon the above limits.

In the case of field riveting (and for bolts as per § 76) the above-allowed shearing strains and pressures shall be reduced one-third.

Rivets and bolts must not be used in direct tension.

54. Pins shall be proportioned so that the shearing strain shall not exceed 10,000 pounds per square inch; nor the pressure on the bearing surface of any member (other than forged eye-bars, see § 104) connected to the pin be greater per square inch than 18,000 pounds; nor the bending strain exceed 20,000 pounds, when the applied forces are considered as uniformly distributed over the middle half of the bearing of each member.

55. When any member is subjected to the action of both axial and bending strains, as in the case of end posts of through bridges (§ 52), or of chords carrying distributed floor loads, it must be proportioned so that the greatest fibre strain will not exceed the allowed limits of tension or compression on that member. Combined Strains.

If the fibre strain resulting from the weight only, of any member, exceeds ten per cent. of the allowed unit strain on such member, such excess must be considered in proportioning the areas.

56. In beams and plate girders the compression flanges shall be made of same *gross* section as the tension flanges. Compression Flanges.

57. Riveted longitudinal girders shall have, preferably, a depth not less than $\frac{1}{20}$ of the span. Depth of Girders.

Rolled beams used as longitudinal girders shall have, preferably, a depth not less than $\frac{1}{30}$ of the span.

58. Plate girders shall be proportioned upon the supposi- Plate Girders etc.

tion that the bending or chord strains are resisted entirely by the upper and lower flanges, and that the shearing or web strains are resisted entirely by the web-plate; no part of the web-plate shall be estimated as flange area.

The distance between centres of gravity of the flange areas will be considered as the effective depth of all girders.

Web Plates. 59. The webs of plate girders must be stiffened at intervals, not exceeding the depth of the girders or a maximum of 5 feet, wherever the shearing strain per square inch exceeds the strain allowed by the following formula:

$$\text{Allowed shearing strain} = 12,500 - 90H,$$

where H = ratio of depth of web to its thickness; but no web-plates shall be less than $\frac{5}{16}$ of an inch in thickness.

Stiffeners. 60. All stiffeners must be capable of carrying the maximum vertical shear without exceeding the allowed unit strain.

$$P = 12,000 - 55\frac{l}{r}.$$

Each stiffener must connect to the webs by enough rivets to transfer the maximum shear to or from the webs (§ 83).

Rolled Beams. 61. Rolled beams shall be proportioned (§§ 45, 48) by their moments of inertia.

Counters. 62. The areas of counters shall be determined by taking the difference in areas due to the live and dead load strains considered separately (§ 45, 105).

63. For bridges carrying electric or motor cars counters shall be provided and proportioned, so that a future increase of 25 per cent. in the specified live load shall not in any case increase the allowed unit strain more than 25 per cent.

DETAILS OF CONSTRUCTION.

Details. 64. All the connections and details of the several parts of the structures shall be of such strength that, upon testing, rupture will occur in the body of the members rather than in any of their details or connections.

65. Preference will be had for such details as shall be most accessible for inspection, cleaning and painting; no closed sections will be allowed.

Riveting. 66. The pitch of rivets in all classes of work shall never

exceed 6 inches, or sixteen times the thinnest outside plate, nor be less than three diameters of the rivet.

67. The rivets used shall generally be $\frac{3}{4}$ and $\frac{7}{8}$ inch diameter.

68. The distance between the edge of any piece and the centre of a rivet-hole must never be less than $1\frac{1}{4}$ inches, except for bars less than $2\frac{1}{2}$ inches wide ; when practicable it shall be at least two diameters of the rivet.

69. For punching, the diameter of the die shall in no case exceed the diameter of the punch by more than $\frac{1}{16}$ of an inch, and all holes must be clean cuts without torn or ragged edges.

70. All rivet holes must be so accurately spaced and punched that when the several parts forming one member are assembled together, a rivet $\frac{1}{16}$ inch less in diameter than the hole can generally be entered, hot, into any hole, without reaming or straining the metal by " drifts "; occasional variations must be corrected by reaming.

71. The rivets when driven must completely fill the holes. The rivet-heads must be round and of a uniform size for the same sized rivets throughout the work. They must be full and neatly made, and be concentric to the rivet-hole, and thoroughly pinch the connected pieces together.

72. Wherever possible, all rivets must be machine driven. The machines must be capable of retaining the applied pressure after the upsetting is completed. No hand-driven rivets exceeding $\frac{7}{8}$ inch diameter will be allowed.

73. Field riveting must be reduced to a minimum or entirely avoided, where possible.

74. All holes for field rivets, except those in connections of the lateral and sway systems, shall be accurately drilled or reamed to an iron template or be reamed true while the parts are temporarily connected together.

75. The effective diameter of a driven rivet will be as- Net Sections. sumed the same as its diameter before driving. In deduct- ing the rivet-holes to obtain net sections in tension members, the diameter of the rivet-holes will be assumed as $\frac{1}{8}$ inch larger than the undriven rivets.

The rupture of a riveted tension member is to be con-

sidered as equally probable, either through a transverse line of rivet-holes or through a diagonal line of rivet-holes, where the net section does not exceed by 30 per cent. the net section along the transverse line.

The number of rivet-holes to be deducted for net section will be determined by this condition.   (§§ 47–79.)

Bolts.   76. When members are connected by bolts the holes must be reamed parallel and the bolts turned to a driving fit. All bolts must be of neat lengths, and shall have a washer under the heads and nuts where in contact with wood. Bolts must not be used in place of rivets, except by special permission.

77. All nuts must be of hexagonal shape.

Splices.   78. All joints in riveted tension members must be fully and symmetrically spliced.

79. Riveted tension members shall have an effective section through the pin-holes 25 per cent. in excess of the net section of the member, and back of the pin at least 75 per cent. of the net section through the pin-hole.

80. In continuous compression members, as chords and trestle posts, the abutting joints with planed faces must be placed as close to the panel points as is practicable, and the joints must be spliced on all sides with at least two rows of closely pitched rivets on each side of the joint.

Joints in long posts must be fully spliced.

Abutting Joints.   81. In compression members, abutting joints with untooled faces must be fully spliced, as no reliance will be placed on such abutting joints. The abutting ends must, however, be dressed straight and true, so there will be no open joints.

Web Splices.   82. The webs of plate girders must be spliced at all joints by a plate on each side of the web.

Stiffeners.   83. All web-plates must have stiffeners over bearing points and at points of local concentrated loadings; such stiffeners must be fitted at their ends to the flange angles, at the bearing points.   (§§ 59–60.)

84. All other angles, filling and splice plates on the webs of girders and riveted members must fit at their ends to

the flange angles, sufficiently close to be sealed, when painted, against admission of water.

85. Web-plates of all girders must be arranged so as not to project beyond the faces of the flange angles, nor on the top be more than $\frac{1}{16}$ inch below the face of these angles, at any point. Web Plates.

86. Wherever there is a tendency for water to collect, the spaces must be filled with a suitable waterproof material.

87. In girders with flange plates, at least one-half of the flange section shall be angles or else the largest sized angles must be used. Flange plates must extend beyond their theoretical length, two rows of rivets at each end. Flange Plates.

88. The flange plates of all girders must be limited in width so as not to extend beyond the outer lines of rivets connecting them with the angles, more than five inches or more than eight times the thickness of the first plate. Where two or more plates are used on the flanges, they shall either be of equal thickness or shall decrease in thickness outward from the angles.

89. The compression flanges of beams and girders shall be stayed against transverse crippling when their length is more than sixteen times their width. Compression Flanges.

90. The unsupported width (distance between rivets) of plates subject to compression shall not exceed thirty times their thickness; except cover plates of top chords and end posts, which will preferably be limited to forty times their thickness; where a greater relative width is used in chords and end posts, however, only forty times the thickness shall be considered as effective section. Width of Plates.

91. In lattice girders and trusses the web members must be double and connect symmetrically to the webs of the chords. The use of plates or flats, alone, for tension members must be avoided, where it is possible; in lattice trusses, the counters, suspenders and two panels of the lower chord, at each end, must be latticed; all other tension members must be connected by batten plates or latticed. (§ 111.)

92. Where the floor timbers are supported at their ends

on the flange of one angle, such angle must have two rows of rivets in its vertical leg, spaced not over 4 inches apart.

Buckle Plates. 93. Buckle plates must be firmly riveted to the supporting beams and be spliced at all free edges. Preferably they will be made in continuous sheets of panel lengths. They may be pressed or formed without heating. (§ 23.)

94. A buckle-plate floor, as specified, may be considered as the required lateral system of bracing at the floor level.

95. The buckle-plates of the sidewalks will be covered to the proper slope and level for the wearing pavement with bitumen concrete of an accepted and waterproof character.

96. The buckle-plates of the roadway will be covered with an acceptable and waterproof concrete (bitumen or cement) to the proper crown and grade for the wearing pavement, but at no place must the concrete be less than 3 inches thick.

Thickness of Metal. 97. For main members and their connections no material shall be used of a less thickness than $\frac{5}{16}$ of an inch; and for laterals and their connections, no material less than $\frac{1}{4}$ of an inch in thickness; except for lining or filling vacant spaces. No bars shall be used with a less net area than $\frac{3}{4}$ of one square inch.

Eye Bars 98. The heads of eye-bars shall be so proportioned and made, that the bars will preferably break in the body of the original bar rather than at any part of the head or neck. The form of the head and the mode of manufacture shall be subject to the approval of the Engineer. (§§ 138, 139, 159, 160.)

99. The bars must be free from flaws and of full thickness in the necks. They shall be perfectly straight before boring. The holes shall be in the centre of the head, and on the centre line of the bar.

100. The bars must be bored to lengths not varying from the calculated lengths more than $\frac{1}{64}$ of an inch for each 25 feet of total length.

101. Bars which are to be placed side by side in the structure shall be bored at the same temperature and of such equal length that upon being piled on each other the

pins shall pass through the holes at both ends without driving.

102. The lower chord shall be packed as narrow as possible.

103. The pins shall be turned straight and smooth; chord Pins. pins shall fit the pin-holes within $\frac{1}{50}$ of an inch, for pins less than $4\frac{1}{2}$ inches diameter; for pins of a larger diameter the clearance may be $\frac{1}{32}$ inch.

104. The diameter of the pin shall not be less than three-quarters the largest dimension of any eye-bar attached to it. The several members attaching to the pin shall be so packed as to produce the least bending moment upon the pin, and all vacant spaces must be filled with wrought filling rings.

105. All bars with screw ends shall be upset at the ends, Upset Ends. so that the diameter at the bottom of the threads shall be $\frac{1}{16}$ inch larger than any part of the body of the bar. Where closed sleeve nuts are used on adjustable members the effective length of thread shall be legibly stamped at the screw ends of each bar. Adjustable counters to be avoided where practicable.

106. All threads must be of the United States standard, except at the ends of the pins.

107. Floor beam hangers when permitted shall be made Hangers. without adjustment and so placed that they can be readily examined at all times. (§ 3.)

108. All the floor beams must be effectually stayed against end motion or any tendency to rotate from the action of the lateral system.

109. Compression members shall be of steel, and of ap-Compression Members. proved forms.

110. The pitch of rivets at the ends of compression members shall not exceed four diameters of the rivets for a length equal to twice the width of the member.

111. The open sides of all compression members shall be stayed by batten plates at the ends and diagonal lattice-work at intermediate points. The batten plates must be placed as near the ends as practicable, and shall have a

length not less than the greatest width of the member or $1\frac{1}{2}$ times its least width. The size and spacing of the lattice bars shall be duly proportioned to the size of the member. They must not be less in width than $1\frac{1}{2}$ inches for members 6 inches in width, $1\frac{3}{4}$ inches for members 9 inches in width, 2 inches for members 12 inches in width, nor $2\frac{1}{4}$ inches for members 15 inches in width, nor $2\frac{1}{2}$ inches for members 18 inches and over in width. Single lattice bars shall have a thickness not less than $\frac{1}{40}$ or double lattice bars connected by a rivet at the intersection, not less than $\frac{1}{60}$ of the distance between the rivets connecting them to the members. They shall be inclined at an angle not less than 60° to the axis of the member for single latticing, nor less than 45° for double latticing with riveted intersections. The pitch of the latticing must not exceed the width of the channel plus nine inches.

112. Where necessary, pin-holes shall be reinforced by plates, some of which must be of the full width of the member, so the allowed pressure on the pins shall not be exceeded, and so the strains shall be properly distributed over the full cross-section of the members. These reinforcing plates must contain enough rivets to transfer their proportion of the bearing pressure, and at least one plate on each side shall extend not less than six inches beyond the edge of the batten plates. (§ 111.)

113. Where the ends of compression members are forked to connect to the pins, the aggregate compressive strength of these forked ends must equal the compressive strength of the body of the members.

114. In compression chord sections and end posts, the material must mostly be concentrated at the sides, in the angles and vertical webs. Not more than one plate, and this not exceeding $\frac{3}{8}$ inch in thickness, shall be used as a cover plate, except when necessary to resist bending strains, or to comply with § 90. (§ 55.)

115. The ends of all square-ended members shall be planed smooth, and exactly square to the centre line of strain.

116. The ends of all floor beams and stringers shall be Floor Beams
and Stringers. faced true and square, and to correct lengths. Allowance must be made in the thickness of the end angles to provide for such facing without reducing the required effective strength of such end angles.

117. All members must be free from twists or bends. Portions exposed to view shall be neatly finished.

118. Pin-holes shall be bored exactly perpendicular to a Pin-Holes. vertical plane passing through the centre line of each member, when placed in a position similar to that it is to occupy in the finished structure.

119. The several pieces forming one built member must fit closely together, and when riveted shall be free from twists, bends or open joints.

120. All through bridges shall have latticed portals, of Transverse Diagonal Bracing approved design, at each end of the span, connected rigidly to the end posts and top chords. They shall be as deep as the specified head-room will allow, and provision shall be made in the end posts for the bending strains from wind pressure. (§§ 4, 10, 39, 52.)

121. When the height of the trusses exceeds 20 feet, an approved system of overhead diagonal bracings shall be attached to each post and to the top lateral struts.

122. Knee braces shall be placed at each intermediate panel point, and connected to the vertical posts and top lateral struts, for trusses 20 feet and less in depth.

123. Pony trusses and through plate or lattice girders shall be stayed by knee braces or gusset plates attached to the top chords at the ends and at intermediate points, and attached below to the cross floor beams or to the transverse struts.

124. All deck girders shall have transverse braces at the ends. All deck bridges shall have transverse bracing at each panel point. This bracing shall be proportioned to resist the unequal loading of the trusses.

125. All members of the web, lateral, longitudinal or sway systems must be securely riveted at their intersections to prevent sagging and rattling.

Bed Plates. 126. All bed-plates must be of such dimensions that the greatest pressure upon the pedestal stone shall not exceed 250 pounds per square inch.

Friction Rollers. 127. All bridges over 80 feet span shall have hinged bolsters on both ends, and at one end nests of turned friction rollers running between planed surfaces. These rollers shall not be less than $2\frac{7}{8}$ inches diameter for spans 100 feet or less, and for greater spans this diameter shall be increased in proportion of 1 inch for 100 feet additional.

The rollers shall be so proportioned that the pressure per lineal inch of roller shall not exceed the product of the diameter in inches by 300 pounds (300d.).

The rollers must be of machinery steel and the bearing plates of medium steel.

The rollers and bearings must be so arranged that they can be readily cleaned and so that they will not hold water.

128. Bridges less than 80 feet span shall be secured at one end to the masonry, and the other end shall be free to move longitudinally upon smooth surfaces.

129. Where two spans rest upon the same masonry, a continuous plate, not less than $\frac{3}{8}$ inch thick, shall extend under the two adjacent bearings, or the two bearings must be rigidly tied together.

Pedestals and Bed-Plates. 130. Pedestals shall be made of riveted plates and angles. All bearing surfaces of the base plates and vertical webs must be planed. The vertical webs must be secured to the base by angles having two rows of rivets in the vertical legs. No base plate or web connecting angle shall be less in thickness than $\frac{1}{2}$ inch. The vertical webs shall be of sufficient height and must contain material and rivets enough to practically distribute the loads over the bearings or rollers.

Where the size of the pedestal permits, the vertical webs must be rigidly connected transversely.

131. All the bed-plates and bearings under fixed and movable ends must be fox-bolted to the masonry; for trusses, these bolts must not be less than $1\frac{1}{4}$ inches diameter; for plate and other girders, not less than $\frac{7}{8}$ inch diameter.

The contractor must furnish all bolts, drill all holes and set bolts to place with sulphur or Portland cement.

132. While the expansion ends of all trusses must be free to move longitudinally under changes of temperature, they shall be anchored against lifting or moving sideways.

133. All bridges shall be cambered by giving the panels Camber. of the top chord an excess of length in the proportion of $\frac{3}{16}$ of an inch to every ten feet.

134. The lower struts in trestle towers must be capable Trestle Towers. of resisting the strains due to changes of temperature or of moving the tower pedestals under the effects of expansion or contraction.

For high or massive towers, these lower struts will be securely anchored to intermediate masonry piers, or the tower pedestals will have suitably placed friction rollers, as may be directed by the Engineer.

135. All joints in the tower columns shall be fully spliced for all possible tension strains, and to hold the parts firmly in position. (§ 80.)

136. Tower footings and bed-plates must be planed on all bearing surfaces; and the holes for anchor bolts slotted to allow for the proper amount of movement. (§ 41.)

137. All workmanship shall be first-class in every par- Workmanship. ticular.

138. All eye-bars must be made of medium steel. Eye-Bars.

139. Eye-bars, all forgings and any pieces which have been partially heated or bent cold must be wholly annealed. Crimped stiffeners need not be annealed.

140. No reliance will be placed upon the welding of steel.

141. No sharp or unfilleted angles or corners will be allowed in any piece of metal.

142. Medium steel may be used in compression in chords, Medium Steel. posts and pedestals without reaming of punched holes, for all thicknesses of metal, which will stand the drifting test § 154); provided all sheared edges are planed off to a depth of $\frac{1}{8}$ inch.

In all other cases medium steel over $\frac{5}{8}$ inch thick must

have all sheared edges planed off to a depth of $\frac{1}{8}$ inch and all holes drilled or reamed to a diameter $\frac{1}{8}$ inch larger than the punched holes, so as to remove all the sheared surface of the metal.

Soft Steel. 143. Soft steel need not be reamed if it satisfies the drifting test (§§ 154, 155).

144. All parts of any tension or compression flange or member, must be of the same kind of steel, but webs of plate girders and the tension members of all girders, plate or lattice, may be made of soft steel in connection with compression members of medium steel.

145. All splices must be of the same kind of steel as the parts to be joined.

Pilot Nuts. 146. Pilot nuts must be used during the erection to protect the threads of the pins. ·

QUALITY OF MATERIAL.

STEEL.

147. All steel must be made by the Open Hearth process. The phosphorus must not exceed 0.06 of one per cent. for steel made by the acid method, or 0.04 for steel by the basic method.

148. The steel must be uniform in character for each specified kind. The finished bars, plates and shapes must be free from cracks on the faces or corners, and have a clean, smooth finish. No work shall be put upon any steel at or near the blue temperature or between that of boiling water and of ignition of hard wood sawdust.

149. The tensile strength, elastic limit* and ductility shall be determined by samples cut from the finished material after rolling. The samples to be at least 12 inches long, and to have a uniform sectional area not less than $\frac{1}{2}$ square inch.

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* For the purpose of these specifications, the Elastic Limit will be considered the least strain producing a visible permanent elongation in a length of 8 inches, as shown by scribe marks of a pair of finely pointed dividers.

If the yield point or drop of the beam can be calibrated for any machine and its speed to represent the elastic limit within 5 per cent., it may be used for general cases. Test reports must state by which method the elastic limit was determined.

150. Material which is to be used without annealing or further treatment is to be tested in the condition in which it comes from the rolls. When material is to be annealed or otherwise treated before use, the specimen representing such material is to be similarly treated before testing, for tensile strength.

The elongation shall be measured on an original length of 8 inches. Two test pieces shall be taken from each melt or blow of finished material, one for tension and one for bending. (Art. 166.)

151. All samples or full-sized pieces must show uniform fine grained fractures of a blue steel-gray color, entirely free from fiery lustre or a blackish cast.

152. **Medium Steel** shall have an ultimate strength, when Medium Steel. tested in samples of the dimensions above stated, of 60,000 to 68,000 pounds per square inch, an elastic limit of not less than one-half of the ultimate strength, and a minimum elongation of 22 per cent. in 8 inches. Steel for pins may have a minimum elongation of 15 per cent.

153. Before or after heating to a low cherry red and cooling in water at 82 degrees Fahr., this steel must stand bending to a curve whose inner radius is one and a half times the thickness of the sample, without cracking.

154. For all medium steel, $\frac{5}{8}$ inch or less in thickness, rivet holes punched as in ordinary practice (§§ 68, 69, 70), must stand drifting to a diameter one-third greater than the original holes, without cracking either in the periphery of the holes or on the external edges of the piece, whether they be sheared or rolled.

155. **Soft Steel** shall have an ultimate strength, on same Soft Steel. sized samples, of 54,000 to 62,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength, and a minimum elongation of 25 per cent. in 8 inches.

For soft steel the above drifting test (§ 154) shall apply to all material to be riveted.

156. Before or after heating to a light yellow heat and quenching in cold water, this steel must stand bending 180

degrees, to a curve whose inner radius is equal to the thickness of the sample, without sign of fracture.

Rivet Steel. 157. **Rivet Steel** shall have an ultimate strength of 50,000 to 58,000 pounds per square inch, an elastic limit not less than one-half the ultimate strength and an elongation of 26 per cent.

158. The steel for rivets must, under the above bending test (156), stand closing solidly together without sign of fracture.

Eye Bars. 159. Eye-bar material, $1\frac{1}{2}$ inches and less in thickness, shall, on test pieces cut from finished material, fill the above requirements. For thicknesses greater than $1\frac{1}{2}$ inches, there will be allowed a reduction in the percentage of elongation of 1 per cent. for each $\frac{1}{8}$ of an inch increase of thickness, to a minimum of 20 per cent. (Art. 138.)

160. Full sized eye-bars shall show not less than 10 per cent. elongation in the body of the bar, and an ultimate strength not less than 56,000 pounds per square inch. Should a bar break in the head, but develop 10 per cent. elongation and the ultimate strength specified, it shall not be cause for rejection, provided not more than one-third of the total number of bars tested break in the head.

Pins. 161. Pins over 7 inches in diameter shall be forged. Blooms for pins shall have at least three times the sectional area of the finished pins.

162. A variation of cross-section or weight in the finished members of $2\frac{1}{2}$ per cent. from the specified size may be cause for rejection.

STEEL CASTINGS.

Steel Castings. 163. Steel castings will be used for drawbridge wheels, track segments and gearing. (Art. 1.)

They must be true to form and dimensions, of a workmanlike finish and free from injurious blowholes and defects. All castings must be annealed.

When tested in specimens of uniform sectional area of at least $\frac{1}{2}$ square inch for a distance of 2 inches, they must

show an ultimate strength of not less than 67,000 pounds per square inch, an elastic limit of one-half the ultimate, and an elongation in 2 inches of not less than 10 per cent.

The metal must be uniform in character, free from hard or soft spots, and be capable of being properly tool finished.

CAST IRON.

164. Except where cast steel or chilled iron is required, Cast Iron. all castings must be of tough, gray iron, free from cold shuts or injurious blowholes, true to form and thickness, and of a workmanlike finish. Sample pieces, 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining, on a clear span of 12 inches, a central load of 2,400 pounds, when tested in the rough bar. A blow from a hammer shall produce an indentation on a rectangular edge of the casting without flaking the metal.

TIMBER.

165. The timber, unless otherwise specified, shall be Timber. strictly first-class spruce, white pine, southern yellow pine or white oak bridge timber, sawed true, and out of wind, full size, free from wind shakes, large or loose knots, decayed or sap wood, worm holes, or other defects impairing its strength or durability. It will be subject to the inspection and acceptance of the Engineer.

INSPECTION.

166. All facilities for inspection of the materials and Inspection. workmanship shall be furnished by the contractor. He shall furnish without charge such specimens (prepared) of the several kinds of steel to be used, as may be required to determine their character.

167. The contractor must furnish the use of a testing machine capable of testing the above specimens at all mills where the steel may be manufactured, free of cost.

168. Full sized parts of the structure may be tested at the option of the Engineer, but if tested to destruction, such material shall be paid for at cost, less its scrap value

to the contractor, if it proves satisfactory. If it does not stand the specified tests, it will be considered rejected material, and be solely at the cost of the contractor.

PAINTING.

Painting. 169. All metal work before leaving the shop shall be thoroughly cleaned from all loose scale and rust, and be given one good coating of pure raw linseed oil, well worked into all joints and open spaces.

Buckle-plates shall be given a thick and thorough coating of red lead and linseed oil before shipment. All rivet heads in the buckle-plate floor shall also be coated with this read lead paint as soon as practicable after they are driven.

170. In riveted work the surfaces coming in contact shall each be painted before being riveted together. Bottoms of bed-plates, bearing-plates, and any parts which are not accessible for painting after erection, shall have two coats of paint; the paint shall be a good quality of iron ore paint, mixed with pure linseed oil.

171. After the structure is erected, the metal work shall be thoroughly and evenly painted with two additional coats of paint, mixed with pure linseed oil. All recesses which will retain water, or through which water can enter, must be filled with thick paint or some waterproof cement before receiving the final painting.

172. Pins, bored pin-holes, screw threads and turned friction rollers shall be coated with white lead and tallow before being shipped from the shop.

ERECTION.

Erection. 173. The contractor, unless it be otherwise specified, shall furnish all staging and false work, shall erect and adjust all the metal work, and put in place all floor timbers, guards, etc., complete.

174. The contractor shall so conduct all his operations as not to interfere with the work of other contractors, or close any thoroughfare by land or water, except by written consent of...............................

175. The contractor shall assume all risks of accidents to men or material prior to the acceptance of the finished structure.

The contractor must also remove all false work, piling and other obstructions, or unsightly material produced by his operations.

FINAL TEST.

176. Before the final acceptance the Engineer may make Final Test. a thorough test by passing over each structure the specified loads, or their equivalent, or by resting the maximum load upon the structure for twelve hours.

After such tests the structures must return to their original positions without showing any permanent change in any of their parts.

EXPORT WORK.

All plans, including working drawings, must be submitted Export Work. for the examination and approval of the Consulting Engineer before the material is ordered or any work done.

Any proposed modification of accepted plans, to adapt them to the plant and methods of the manufacturer or to facilitate the prompt delivery of the work, must also be submitted to and approved by the Consulting Engineer, before such changes can be allowed.

In all designs, the length and size of parts must be so arranged that they can be readily handled and stored during transportation to the site.

Length of bars, posts, chords and pieces of small section must not exceed...feet.

Length of girders or girder sections over.......................feet in width must not exceed...feet.

Weight of any single piece must not exceed................................. pounds.

Pins, roller-nests, bolts, rivets and all small pieces must be packed in strong, iron-bound boxes, with the detailed contents of each box legibly marked on the outside. Boxes to be consecutively lettered or numbered.

The screw-ends of all bars to be securely protected by canvass wrapped and wired about the same.

Every piece must not only be legibily marked by paint, but also by letters stamped on the metal, showing its location in the structure.

All necessary rivets for the field connections, with an extra allowance of 25 per cent. for each kind, shall be sent with each shipment.

The customary pilot-nuts (§ 146) for all pins shall be sent with the pins.

SUPPLEMENTARY.

The following special clauses shall apply in addition to previous general clauses, to the special work included in the attached contract:

GENERAL DATA.

For a bridge crossing_____ _____in the town
   of_____ ____County of_____State of
   _____to be built according to the general
   requirements of the accompanying specifications:

Width of roadway_____
Number of footwalks_____
Width of footwalks_____
Kind of floor or paving_____
Number of car tracks_____
Spacing   "   "   _____
Height of floor above flood line_____
Height of floor above ordinary stage of water_____
Depth of river at ordinary stage of water_____
Character of river bed_____
Usual seasons for floods_____
Length of haul from nearest freight station_____
Specified live load, Class A1, A2, B, C, D, E1 or E2, para-
   graph 38, to be adopted for this bridge_____
Sizes of piers (if built or contracted for)_____
Skew of piers, or angle of current with line of the bridge_
Total length of bridge_____
Length of spans centre to centre of piers_____

APPENDIX.

TABLE I.

Maximum End Shears S, Moments M, and Reactions R for Live Loads (only), on Stringers and Floor-Beams of Class E_1.

Span.	Each stringer.			Floor-Beams.			
				Single track.		Double track.	
$L.$ Ft.	$S.$ Lbs.	$M.$ 1 000 inch-lbs.	Least size.	$R.$ Lbs.	$M.$ Lbs.-ft.	$R.$ Lbs.	$M.$ Lbs.-ft.
10	12 000	360		12 000	....	24 000	....
11	13 100	396	12-in. $I.$				
12	14 000	432					
13	14 800	468					
14	15 400	504	....				
15	16 000	540					
16	16 500	576					
17	16 900	612					
18	17 300	676	15-in. $I.$		$M = \dfrac{S}{2}\,(d-f).$		$M = S\,(d-e).$
19	17 700	743					
20	18 000	810					
21	18 300	878	....	$R = S.$		$R = 2\,S.$	
22	18 500	946					
23	18 800	1 014	18-in. $I.$				
24	19 000	1 083	....				
25	19 200	1 152					
26	19 400	1 221					
27	19 600	1 291	20-in. $I.$				
28	19 700	1 360					
29	19 900	1 430					
30	20 000	1 500	....	20 000	....	40 000	....

$$S = P\left(1 + \frac{l - 10}{l}\right)$$

Moment for stringers equals

$$M = \frac{Pl}{4} \text{ up to 17 feet.}$$

$$M = P\,\frac{(l-5)^2}{2\,l} \text{ over 17 feet, in foot-pounds.}$$

S = end shear of one stringer.
M = maximum moment.
P = concentrated load on one wheel.
l = span in feet.
d = distance in feet, center to center of trusses.
e = distance in feet, center to center of tracks.
f =   "   "   "   "   stringers.

TABLE II.

Same for Class E₂.

Span.	Each stringer.			Floor-Beams.			
				Single track.		Double track.	
$L.$ Ft.	$S.$ Lbs.	$M.$ 1 000 inch-lbs.	Least size.	$R.$ Lbs.	$M.$ Lbs. ft.	$R.$ Lbs.	$M.$ Lbs. ft.
10..................	9 000	270	10-in. $I.$				
11..................	9 800	297	....				
12..................	10 500	324					
13..................	11 100	351					
14..................	11 600	378	12-in. $I.$				
15..................	12 000	405					
16..................	12 400	432					
17..................	12 700	459					
18..................	13 000	507	....				
19..................	13 300	557					
20..................	13 500	607					
21..................	13 700	658	15-in. $I.$				
22..................	13 900	709		$R = S.$	$M = \dfrac{S}{2}(d-f).$	$R = 2 S.$	$M = S(d-e).$
23..................	14 100	761					
24..................	14 200	812	....				
25..................	14 400	864					
26..................	14 500	916	18-in. $I.$				
27..................	14 700	968	....				
28..................	14 800	1 020					
29..................	14 900	1 073					
30..................	15 000	1 125	20-in. $I.$				

TABLE III.

MAXIMUM END SHEARS S, MOMENTS M AND REACTIONS R FOR LIVE LOADS (ONLY) ON STRINGERS AND FLOOR-BEAMS OF CLASSES A AND B, WITH DOUBLE-TRACK RAILWAY.

Span.	Each Stringer.					Floor-Beams (A and B). Width of roadway.					
	A. All.	B. Under tracks.	B. Under roadway.								
L. Ft.	S. and M.	S and M.	S. Lbs.	M. 1000 inch-lbs.	Least size.	20 ft. R. Lbs.	24 ft. R. Lbs.	28 ft. R. Lbs.	32 ft. R. Lbs.	36 ft. R. Lbs.	40 ft. R. Lbs.
10	Same as for F₁, double track.	Same as for F₁, double track.	6 000	180	9-in. I	24 000	25 000	27 000	29 000	31 000	33 000
11			6 500	198	....	26 200	27 300	29 500	31 700	33 900	36 100
12			7 000	216	....	28 000	29 200	31 600	34 000	36 400	38 800
13			7 400	234	....	29 600	30 800	33 400	36 100	38 600	41 200
14			7 700	252	....	30 800	32 300	35 000	37 800	40 700	43 500
15			8 000	270	10-in. I	32 000	33 500	36 500	39 500	42 500	45 500
16			8 300	288	....	33 000	34 600	37 800	41 000	44 200	47 400
17			8 500	306	....	33 900	35 600	39 000	42 400	45 000	49 200
18			8 700	338	....	34 700	36 600	40 600	43 700	47 300	50 900
19			8 800	371	....	35 400	37 300	41 100	44 900	48 700	52 500
20			9 000	405	12-in. I	36 000	38 000	42 000	46 000	50 000	54 000
21			9 100	439	....	36 600	38 700	42 900	47 100	51 300	55 500
22			9 300	473	....	37 200	39 300	43 700	48 100	52 500	56 900
23			9 400	507	....	37 600	39 900	44 500	49 100	53 700	58 300
24			9 500	541	....	38 000	40 400	45 200	50 000	54 800	59 600
25			9 600	576	....	38 400	40 900	45 900	50 900	55 900	60 900
26			9 700	611	15-in. I	38 800	41 400	46 600	51 800	57 000	62 200
27			9 800	646	....	39 100	41 800	47 200	52 600	58 000	63 400
28			9 900	680	....	39 400	42 200	47 800	53 400	59 000	64 600
29			9 900	715	....	39 700	42 600	48 400	54 200	60 000	65 800
30			10 000	750	....	40 000	43 000	49 000	55 000	61 000	67 000

$$R = 2S + \frac{w-22}{2} \, 100 \, l \text{ for widths over 22 feet.}$$

$$M = \frac{R}{2}(d-e) - \frac{w-22}{8}(w+22-2e)\,100\,l \text{ in foot-pounds.}$$

e = distance c. to c., of tracks.

d = " " " trusses.

w = width of roadway in the clear

l = span of stringers in feet.

TABLE IV.

MAXIMUM END SHEAR S, MOMENTS M AND REACTIONS R, FOR LIVE LOAD (ONLY) ON STRINGERS AND FLOOR-BEAMS OF CLASS C, WITH SINGLE-TRACK RAILWAY.
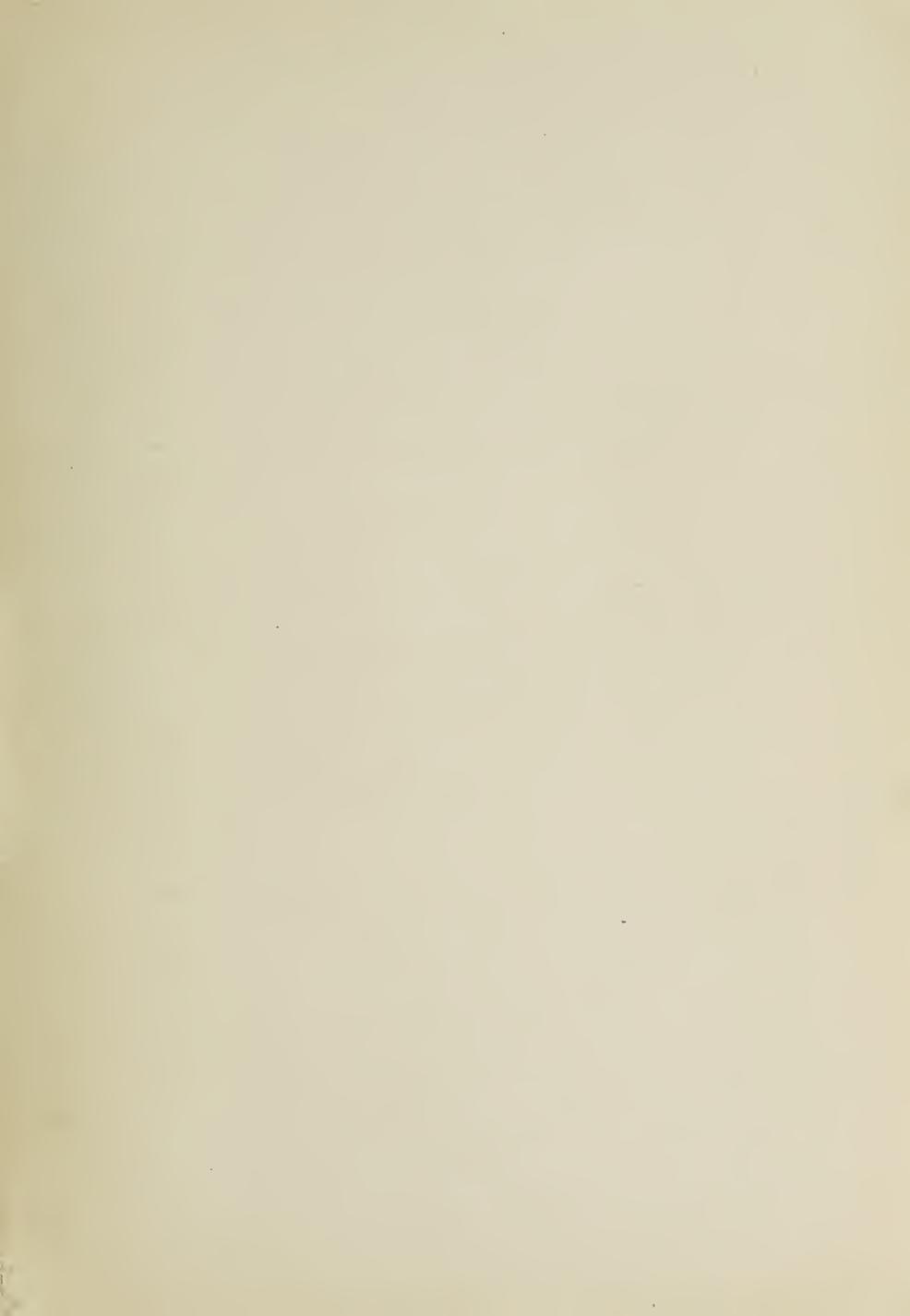
Span L. Ft.	EACH STRINGER			FLOOR-BEAMS				
	Under roadway			Width of roadway				
				12-ft. track, central.		18-ft. track one side; center of track 5 ft. clear of truss.		
	S. lbs.	M. 1000-inch lbs.	Least size.	R. lbs.	M† 1000-inch lbs.	R_1 lbs.	R_2 lbs.	M† 1000-inch lbs.
10	6 000	180		9 000	459	13 800	10 200	830
11	6 500	198	9-in. I.	9 800	500	15 100	11 100	908
12	7 000	216		10 500	536	16 200	12 000	973
13	7 400	234	......	11 100	565	17 100	12 900	1 031
14	7 700	252		11 600	590	17 900	13 600	1 081
15	8 000	270	10-in. l.	12 000	612	18 600	14 400	1 126
16	8 300	288		12 400	631	19 300	15 000	1 168
17	8 500	306	......	12 700	648	19 900	15 700	1 205
18	8 700	338		13 000	663	20 400	16 400	1 241
19	8 800	371		13 300	676	20 900	17 000	1 273
20	9 000	405		13 500	688	21 300	*18 000	1 304
21	9 130	439		13 700	699	21 800	*18 900	1 331
22	9 300	473	12-in. I.	13 900	709	22 200	*19 800	1 359
23	9 400	507		14 100	719	22 570	*20 700	1 385
24	9 500	541	......	*14 400	727	22 900	*21 600	1 409
25	9 600	576		*15 000	734	23 200	*22 500	1 432
26	9 700	611		*15 600	742	23 500	*23 400	*1 444
27	9 800	646	15-in. l.	*16 200	748	*24 300	*24 300	*1 531
28	9 900	680		*16 800	*756	*25 200	*25 200	*1 588
29	9 900	715		*17 400	*783	*26 100	*26 100	*1 644
30	10 000	750		*18 000	*810	*27 000	*27 000	*1 701

Under tracks: S. and M. — Same as for E₃, single track.

For bridges with one track on one side of roadway only.

$$R_1 = S + \frac{(w-12)\, l p}{2} + 2\,a\,S - \frac{(w-12)\, 6\, l p}{D} \quad \text{do.}$$ For concentrated load.

R_2 = do.

$$M \text{ under inner rail} = \frac{R_1}{2}\,(D + 5 - 2a) - 5\,S.$$

For uniform load.

$$R_1 = R_2 = \frac{w}{2}\, p\, l.$$

$$M = \frac{w}{2}\, p\, l\, \frac{2D - w}{4}$$

w = width of roadway.
l = length of panel.
p = uniform load per square foot.
D = width of bridge, center to center of trusses.
a = distance between center of track and center of roadway.

* Maximum from load per square foot.
† Moments calculated for chords 18 ins. wide.

TABLE V.

MAXIMUM END SHEARS S, MOMENTS M AND REACTIONS R FOR LIVE LOAD (ONLY) ON STRINGERS AND FLOOR-BEAMS, CLASS D.

Span.	Stringers (each).			FLOOR-BEAMS. Width of roadway.									
				12 ft.		14 ft.		16 ft.		18 ft.		20 ft.	
L. Ft.	S. lbs.	M 1 000 inch-lbs.	Least size. §17.	R. lbs.	M. 1 000 inch-lbs.	R. lbs.	M. 1 000 inch-lbs.	R. lbs.	M. 1 000 inch-lbs.	R. lbs.	M. 1 000 inch-lbs.	R. lbs.	M. 1 000 inch-lbs.
10	3 000	90	Yellow Pine, 3 x 12..	4 800	216	5 600	286	6 400	365	7 200	454	8 000	552
11	3 300	99	or	5 300	238	6 200	314	7 000	401	7 900	499	8 800	607
12	3 500	108	Spruce. 4 x 12......	5 800	259	6 700	343	7 700	438	8 600	544	9 600	662
13	3 700	117		6 200	281	7 300	371	8 300	474	9 400	590	10 400	718
14	3 900	126	4 x 12, Y. P. or......	6 700	302	7 800	400	9 000	511	10 100	635	11 200	773
15	4 000	135	4 x 14. S.....	7 200	324	8 400	428	9 600	547	10 800	680	12 000	828
16	4 100	144		7 700	346	9 000	457	10 200	584	11 500	726	12 800	883
17	4 200	153	4 x 14, Y. P. or......	8 200	367	9 500	486	10 900	621	12 200	771	13 600	938
18	4 300	169	4 x 15, S.....	8 600	388	10 100	515	11 500	657	13 000	816	14 400	994
19	4 400	186		9 100	410	10 600	544	12 200	693	13 700	862	15 200	1 049
20	4 500	203		9 600	432	11 200	572	12 800	730	14 400	907	16 000	1 104
21	4 600	220		10 100	454	11 800	601	13 400	766	15 100	953	16 800	1 159
22	4 700	237	10-in. I. beam.	10 600	475	12 300	629	14 100	803	15 800	998	17 600	1 214
23	4 700	254		11 000	497	12 900	657	14 700	839	16 600	1 043	18 400	1 270
24	4 800	271		11 500	518	13 400	686	15 400	876	17 300	1 089	19 200	1 325
25	4 800	288		12 000	540	14 000	714	16 000	912	18 000	1 134	20 000	1 380
26	4 900	305		12 500	562	14 600	743	16 600	948	18 700	1 179	20 800	1 435
27	4 900	323		13 000	583	15 100	771	17 300	985	19 400	1 225	21 600	1 490
28	4 900	340		13 500	605	15 700	800	17 900	1 021	20 200	1 270	22 400	1 546
29	5 000	357		13 900	626	16 200	828	18 600	1 058	20 900	1 316	23 200	1 601
30	5 000	375	12-in. I. beam.	14 400	648	16 800	857	19 200	1 094	21 600	1 361	24 000	1 656
31	5 000	392											
32	5 100	410											
33	5 100	428											
34	5 100	445											
35	5 100	463											
36	5 200	480											
37	5 200	498	15-in. I. beam.										
38	5 200	516											
39	5 300	534											
40	5 300	551											

The floor-beam moments in above table are calculated for a width of truss of 18 inches. For other widths take the following percentages of the above moments from the table.

For floor-beams:

$$M = R\,\frac{2D - w}{4}\;;\; R = 40\,w\,l.$$

Width of roadway	WIDTH OF TRUSS.				
	12 ins.	15 ins.	18 ins.	21 ins.	24 ins.
12 ft.	96%	98%	100%	102%	104%
14 "	97 "	98 "	100 "	102 "	104 "
16 "	97 "	99 "	100 "	101 "	103 "
18 "	98 "	99 "	100 "	101 "	103 "
20 "	98 "	99 "	100 "	101 "	102 "

General specifications for steel highway and electric railway bridges and viaducts.

New and revised edition